I. Background

The Mini‑Mental State Examination, or MMSE, is a test of cognitive function with a total possible score of 30 points.It includes tests of orientation, concentration, attention, verbal memory, naming and visuospatial skills. The Mini‑Mental State Examination (MMSE) is the best‑known and the most often used short screening tool for providing an overall measure of cognitive impairment in clinical, research and community settings.

II. Research Question

The main research question of this study is: How do Mini‑Mental State Examination (MMSE) scores vary across different dementia condition groups (demented, nondemented, converted) over time, and what are the implications of these variations for understanding the progression of cognitive impairment?

The analysis is aimed to study:

1. Group differences, meaning how MMSE scores differ among individuals classified as demented, nondemented, or converted,
2. Temporal Changes, meaning if there are significant changes in MMSE scores from Visit 1 to Visit 2 within the same individuals, indicating the progression or stability of cognitive function over time,
3. Conversion trends, meaning if there is a statistically significant trend indicating a decline in MMSE scores for conversion to dementia, and what this suggests about the cognitive trajectory of individuals transitioning to dementia?

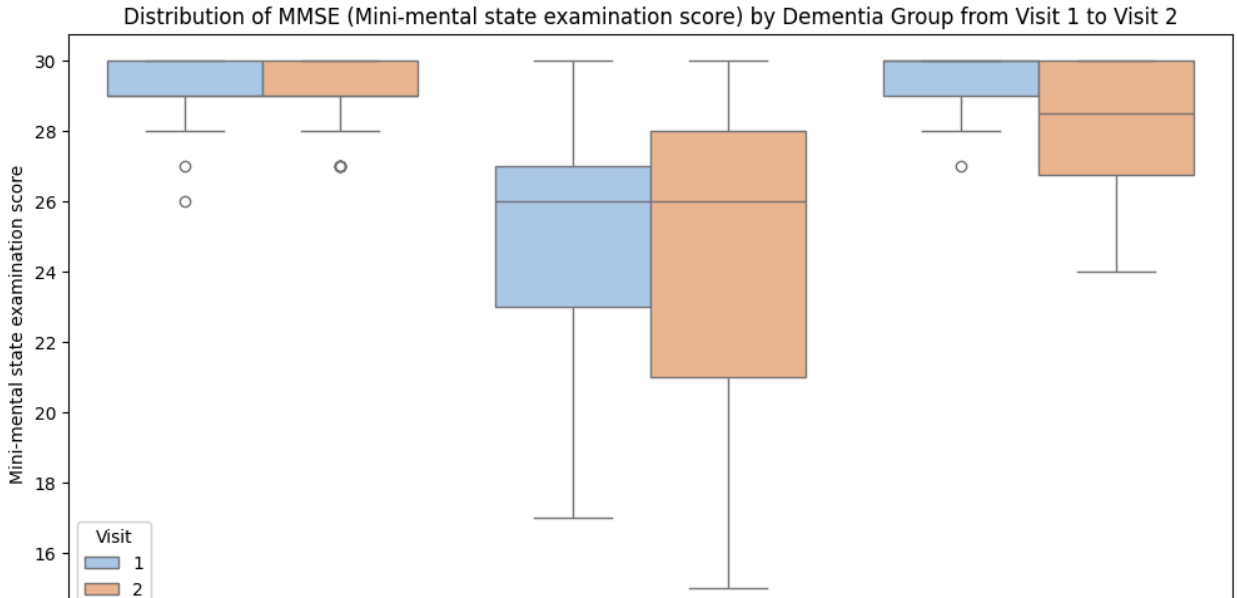
III. Analysis

The exploratory analysis focused on MMSE score dynamics within three distinct groups identified as demented, nondemented, and converted, and showed significant disparity in MMSE scores across three groups. The Nondemented group, as the majority of the subjects in the dataset, has the highest average MMSE score, and the lowest standard deviation. In contrast, the demented group has the lowest average MMSE score across the three groups, indicating low cognitive performance on average, with the highest fluctuations indicated by a standard deviation of 3.92 points.

Group	Mean	Median	Min	Max	Standard Deviation	Count
Converted	28.67	29	24	30	1.74	24
Demented	24.73	26	15	30	3.92	122
Nondemented	29.15	29	26	30	0.91	140

Table 1. Statistics Summary by Dementia Condition Groups

A visual representation (Figure 1) showed similar patterns of MMSE distributions across three groups for both Visit 1 and 2, with the demented and converted groups having much larger



interquartile range (IQR) for Visit 2 compared to Visit 1. As a result, further analysis is needed to explore if there is any significant difference in trends in MMSE scores for the three subject groups.

Source	Sum of Squares (SS)	Degrees of Freedom 1 (DF1)	Degrees of Freedom 2 (DF2)	Mean Square (MS)	F Value (F)	p-Value (unc)	Partial Eta Squared (np2)	Epsilon (eps)
Group	1328.421	2	140	664.211	56.212	0	0.445	NaN
Visit	22.378	1	140	22.378	8.859	0.003	0.06	1
Interaction	17	2	140	8.5	3.365	0.037	0.046	NaN

Table 2. Mixed-effects ANOVA of MMSE Score

- The main effect of dementia condition grouping is significant ($p < 0.001$), with a very large effect size (partial $\eta^2 = 0.445$). This indicates that the average MMSE scores differ significantly across the three clinical status groups (demented, nondemented, or converted). Given the large effect size, clinical status is a major factor affecting cognitive function as measured by the MMSE.
- The main effect of visit number is also significant ($p = 0.003$), with a small effect size (partial $\eta^2 = 0.060$). This suggests that there is a significant difference in MMSE scores between the two visits. The small effect size implies that while statistically significant, the magnitude of change over time within subjects is not as pronounced as the differences between groups.
- The interaction between dementia conditions and visit number is significant ($p = 0.037$), with a small effect size (partial $\eta^2 = 0.046$). This indicates that the change in MMSE scores from Visit 1 to Visit 2 is not consistent across groups. In other words, how MMSE scores change over time may depend on whether the individual is demented, nondemented, or has converted (perhaps from nondemented to demented).

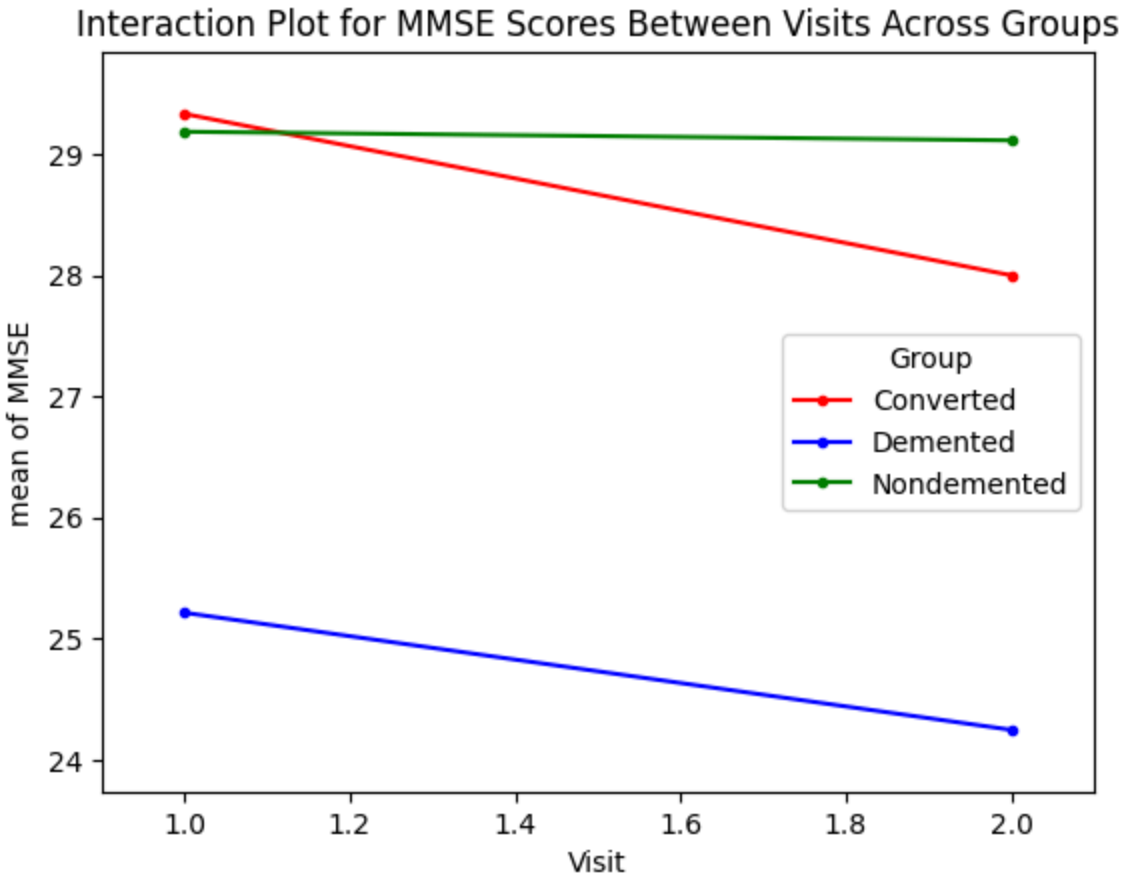


Figure 2. Interaction Plot for MMSE Scores Between Visits Across Groups

Next a post-hoc Tukey test was conducted with a power of 0.05 to study the differences in progressions in MMSE scores from Visit 1 to Visit 2 across groups and showed the results below.

Group1	Group2	Mean Difference	p-adj	Lower Bound	Upper Bound	Reject
Converted	Demented	-3.9372	0	-5.3522	-2.5221	TRUE
Converted	Nondemented	0.4833	0.695	-0.9167	1.8834	FALSE
Demented	Nondemented	4.4205	0	3.6356	5.2054	TRUE

Table 3. Within Group Post-hoc Test results

For between group comparisons, results show that the mean MMSE scores for the converted group and for the demented group are both significantly higher than the demented' group. However, we do not reject the null hypothesis that there is no significant difference in MMSE

scores between the 'Converted' and 'Nondemented' groups.

Comparison Group	Group1	Group2	Mean Difference	p-adj	Lower Bound	Upper Bound	Reject
Nondemented	1	2	-0.0714	0.6422	-0.3748	0.2319	FALSE
Demented	1	2	-0.9672	0.1746	-2.3694	0.4349	FALSE
Converted	1	2	-1.3333	0.058	-2.7159	0.0492	FALSE

Table 4. Between Group Post-hoc Test results

For within group comparisons, while there was no significant change in MMSE scores over time within any group, the converted group showed a trend towards a decrease in scores with a p-value of 0.058, close to the threshold for statistical significance. This suggests a trend where the 'Converted' group may have experienced a decline in MMSE scores from Visit 1 to Visit 2, which indicated the need for a larger sample size or additional visits to better confirm this trend.

A paired t-test was conducted on MMSE score for the converted group between Visit 1 and Visit 2 with a power analysis. A p-value of 0.0504 again landed just above the statistical significance threshold, but the power analysis (Figure 3) indicated that the appropriate sample size for a theoretical experiment with power = 0.91, alpha = 0.05, and effect size = 0.7 would be 46, confirming that a much larger sample than the current sample of 12 subjects is needed to study

the progression of MMSE scores in conversion to dementia.

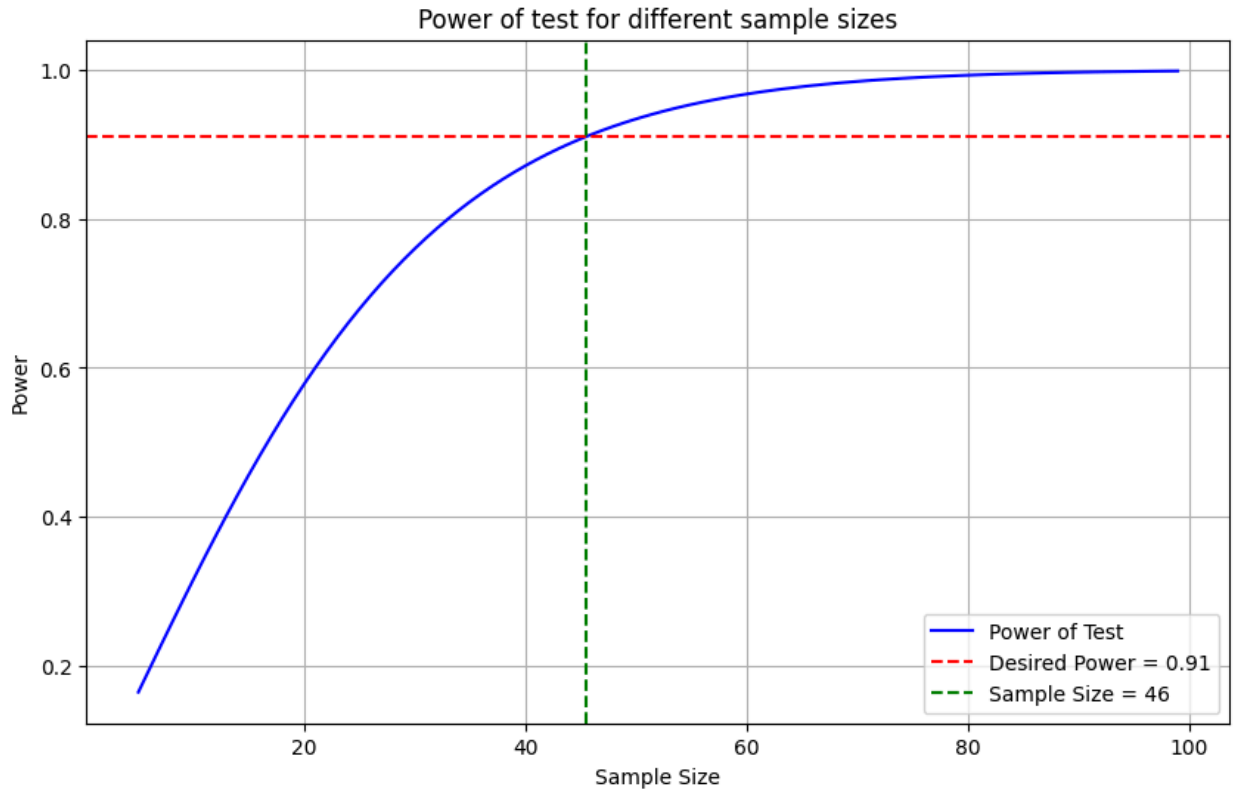


Figure 3. Power of Test for Different Sample Sizes

IV. Findings

The analysis of Mini‑Mental State Examination (MMSE) scores across different dementia condition groups (demented, nondemented, converted) over time has yielded significant insights into the dynamics of cognitive impairment. Firstly, the disparity in MMSE scores across the three groups is pronounced, with the nondemented group showing the highest average scores and the lowest variability, while the demented group had the lowest average scores and highest variability. This variability highlights the impact of dementia conditions on cognitive function, as measured by MMSE.

The statistical analysis revealed that the grouping by dementia condition significantly affects MMSE scores ($p < 0.001$) with a very large effect size, underscoring the influence of clinical status on cognitive functions. The significant main effect of visit number ($p = 0.003$) with a small effect size suggests a subtle yet statistically significant change in cognitive function over time within subjects. Furthermore, the interaction between dementia conditions and visit number was significant ($p = 0.037$), indicating that the progression of cognitive impairment varies across different dementia statuses.

Interestingly, post-hoc tests revealed no significant change in MMSE scores over time within any group, although there was a near-significant trend for the converted group indicating a potential decline in cognitive function from Visit 1 to Visit 2. This suggests that while immediate changes in MMSE scores may not be evident, there could be a gradual decline in cognitive function, especially in individuals transitioning to dementia.

V. Conclusion

The findings from this study emphasize the complexity of cognitive impairment progression across different dementia conditions. The significant difference in MMSE scores across dementia condition groups reaffirms the MMSE's utility in differentiating between various stages of cognitive impairment. The interaction effect between visits and dementia conditions highlights the importance of longitudinal studies in understanding the progression of cognitive impairment.

While this analysis did not find significant temporal changes within groups, the trend observed in the converted group signals the potential for cognitive decline over time, which warrants further investigation. The need for a larger sample size to achieve statistical significance in future studies was also highlighted, suggesting that the progression of cognitive impairment,

particularly in individuals converting to dementia, is an area that requires more extensive research.

Overall, this study contributes to the understanding of how cognitive impairment, as measured by the MMSE, varies across different stages of dementia and over time. This understanding is crucial for early intervention, monitoring disease progression, and tailoring treatment strategies to individual needs. Further research with larger sample sizes and over more extended periods is essential to deepen the understanding of these dynamics and to improve the care and management of individuals with cognitive impairment.